Exhibit C

Plastics Additives Handbook

Stabilizers, Processing Aids, Plasticizers, Fillers, Reinforcements, Colorants for Thermoplastics

4th Edition

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Preface to the Fourth Edition

The third edition of the Plastics Additives Handbook sold out completely within three years, a very clear indication that this book is needed and appreciated by the plastics community.

Not much has changed during this period in the technology of plastics additives. However, major changes are evident in the market scenario. The publishers thus decided not just to reprint the third edition but to correct errors and update the Index of trade names, manufacturers and suppliers. So this fourth edition is actually not a revised edition with major changes but is composed of the text of the third edition with an updated index of suppliers for each group of additives. Our thanks to the authors for their help and advice.

The Editors

Spring 1993

Preface to the first edition

The vigor of the plastics industry remains unbroken but there has been a shift in emphasis with regard to technical development. Today front stage is occupied by the development of plastics and plastics systems, tailor-made for specific applications.

Along with copolymers and physical blends of various plastics, additives are enjoying a key position within this new trend in development. They permit the use of plastics in applications where the plastics material as such would have had small chance of success.

Additives are accepted today as full-fledged partners of plastics. In this sense, this Additives Handbook is a logical and long overdue complement to the trade literature. The Additives Handbook is a reference book having as objective to summarize the state of the art achieved in this area. Next to this somewhat static point of view, attempts have been made to present an outlook of the future, whenever relevant technical trends could be discerned at this time. It is hoped in this way to stimulate further, in depth collaboration among plastics producers, plastics processors, and additives manufacturers. This in turn should lead to long term meaningful problem solutions, thereby further strengthening the position of plastics materials in technology and the economy in general.

tion of the compound from the surface as well as by migration into the bulk of the polymer.

A very important technical consequence of the migration behavior of antistatic agents, which has rarely been taken into consideration in the past, is their possible interaction with highly dispersed goods packed in plastics materials. In unfavorable cases, products with a very large specific surface such as pigments can adsorb the antistatic active substance to the same degree as it diffuses from the polymer to the surface (table 1).

13.3.6 Bulk conductivity

Polymeric materials are used to an increasing extent in technical fields where the surface resistance must not exceed 10^6 Ohm. Such a value cannot be achieved with mechanisms of ion conductivity as shown by incorporable or external antistatic agents; electron conductivity [10, 11] must be used. The relevant fields of application are as follows:

- Use of devices in fields sensitive to explosion such as mining, handling of solvents or finely dispersed goods such as powdery polymers,
- physiologically sensitive work places such as operating rooms or precision engineering,
- protection of sensitive electronic chips during transport and handling as well as in use against destruction by discharge sparks,
- use of electronic switches,
- screening against electromagnetic radiation, casings for electronic instruments.

The agents for such conductivity are mainly carbon black and metals. In order to obtain the required effect, the named products must be dispersed in the plastics melt in a way that allows for uninterrupted contact between the conductive particles. Therefore, a finely divided form of the filler and optimum dispersion are necessary. In polyolefins, a volume resistivity of 10^2 Ohm·cm is achieved [12] with common carbon black types in concentrations of 10 to 25%. This level of conductivity can be reached with 2% of special (conductive) carbon black types and a nonstatistic filler distribution (core/jacket structure). With high filler contents, the mechanical properties of the plastics material are, of course, drastically changed. Polymers containing percolation networks with a refined structure depend mainly on processing conditions for their electrical properties. Crystallinity and degree of orientation of the plastic are of significant influence.

Better conductivity than with carbon black can be achieved with metal particles (volume resistivity approx. 0.1 Ohm·cm). Common are copper or aluminum in the form of powders or flakes, as well as brass, carbon and stainless steel fibers. To increase the effective surface, electrically neutral filler particles are coated with metals, e.g. nickel-plated glass fibers or small spheres, silver- or nickel-plated mica or silicates [13].

There have been recent developments called "intrinsically conductive organic compounds" to produce plastics with tailor-made electrical properties [14]. Transferring the flexibility of the polymeric materials with regard to their mechanical properties and their easy processability to their electrical behavior and creating completely new property combinations, is a fascinating idea and has resulted in extensive literature in a short period of time (survey in [15]). These approaches are based on the principle of producing electronic conductivity in semiconductors by suitable doping and can be classified in two main groups [16]:

- Polymers with high conjugation (e.g. polyacetylene, polyphenylene, polypyrrol, polyphenylene sulfide, polythiophene),
- charge transfer complexes (mainly of tetracyanoquinodimethane).

Doping is made in both cases by partial oxidation (e.g. with Iodine, $FeCl_3$, AsF_5 etc.) or by reduction (sodium, potassium, sodium naphthalide, lithium benzophenonate).

Due to their chemical composition, intrinsically conductive polymers are still causing great problems with regard to chemical [15, 17] and physical [18] aging resistance. Also in the case of the aforementioned conductive fillers such as carbon black or metal particles, the stability of the finished polymer has to be assessed carefully as these fillers may accelerate, as catalysts, the oxidative degradation of the matrix, as well as adsorb onto their large surface the added antioxidants and other additives, thus rendering them ineffective.

All of the mentioned systems which are used to increase bulk conductivity are highly colored due to the electron mobility necessary to achieve the effect. So far, a degree of transparency can be obtained only with conductive polymers in the form of extremely thin coatings.